MACROINVERTEBRATE FAUNA AND WATER QUALITY IN TWO IRRIGATION CHANNELS IN THE SHEPPARTON IRRIGATION REGION, VICTORIA

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A large amount of water is diverted from rivers into irrigation channels in northern Victoria, but little is known of the biological communities of irrigation channels. A preliminary survey of macroinvertebrates and water quality was conducted in two irrigation channels southwest of Shepparton, Victoria. The macroinvertebrate fauna was relatively rich when compared to the surveys in disturbed streams in northern Victoria. Macroinvertebrate population and community structure changed with distance downstream in both channels. Taxa richness and abundance decreased and the community become more depauperate with increasing distance downstream. Similarly, water quality deteriorated with distance downstream in both channels, with EC turbidity, NO_2–N, and PO_4 increasing downstream in both channels, while, NO_3–N concentration decreased in only one of the two channels. However, the temporal stability of these relationships is unknown. There is scope for considerable biological investigations in irrigation channels, which would have practical and theoretical outcomes.

Key words: aquatic macroinvertebrates, water quality, Shepparton Irrigation Region, irrigation channels, longitudinal changes.

MANY macroinvertebrate surveys have been conducted in streams, lakes and artificial impoundments in Victoria. However, despite the widespread occurrence of open irrigation channels throughout northern Victoria, there are few records of macroinvertebrate surveys in irrigation channels.

Irrigation channels have been designed, constructed and managed for the supply of irrigation water to farms and no attempt has been made in their design or management to benefit aquatic biota. However, water quality and biological health of irrigation channels are issues as overflow from irrigation channels generally flows back into rivers. This paper reports on a macroinvertebrate survey in two irrigation channels in the Shepparton Irrigation Region. The original aim of the survey was to investigate the effect of saline water disposal into one of the two channels on macroinvertebrates. Contrary to expectations, large longitudinal changes in macroinvertebrates and water quality swamped any changes due to saline water disposal in both channels, so this paper reports only on these longitudinal changes.

METHODS

Site information

Macroinvertebrates were sampled from 19 sites along two irrigation channels (Channels 2 and 4), approximately 15 km southwest of Shepparton near the town of Murchison. Both channels are supplied with water from the Stuart Murray Canal, which is supplied with Goulburn River water diverted at the Goulburn Weir near Nagambie.

Channel 2 varied in width between 4 and 10 m, while Channel 4 varied between 9 and 15 m. Both channels were elevated above the surrounding land by means of earthen levee banks, and the only riparian vegetation tended to be grasses, sedges and the occasional shrub. The channels commonly had a band of aquatic macrophytes along both sides with a width up to 3 m. The substrata of each channel was mud. Channel 4 received saline ground water disposed into it at several places. While Channel 2 received a smaller amount of saline water at the northern (downstream) end, which potentially affected two sites (Kefford 1996).

Channel	Statistic	EC	Temperature	DO	pH	NO_3–N	NO_2–N	PO_4	Turbidity
4	Minimum	49	20	7.3	6.57	0.09	0.002	0.06	28
4	Maximum	245	25	15.9	8.37	2.10	0.041	0.17	67
4	Median	125	22	8.6	6.91	1.01	0.009	0.07	40
4	Mean	122	22	10.8	7.03	1.05	0.015	0.09	42
2	Minimum	44	19	7.4	6.25	0.10	0.007	0.06	38
2	Maximum	180	25	8.1	7.36	0.13	0.046	0.23	255
2	Median	45	23	7.6	6.95	0.10	0.039	0.13	78
2	Mean	76	22	7.7	6.90	0.10	0.033	0.13	97

Table 1. Summary of water quality.

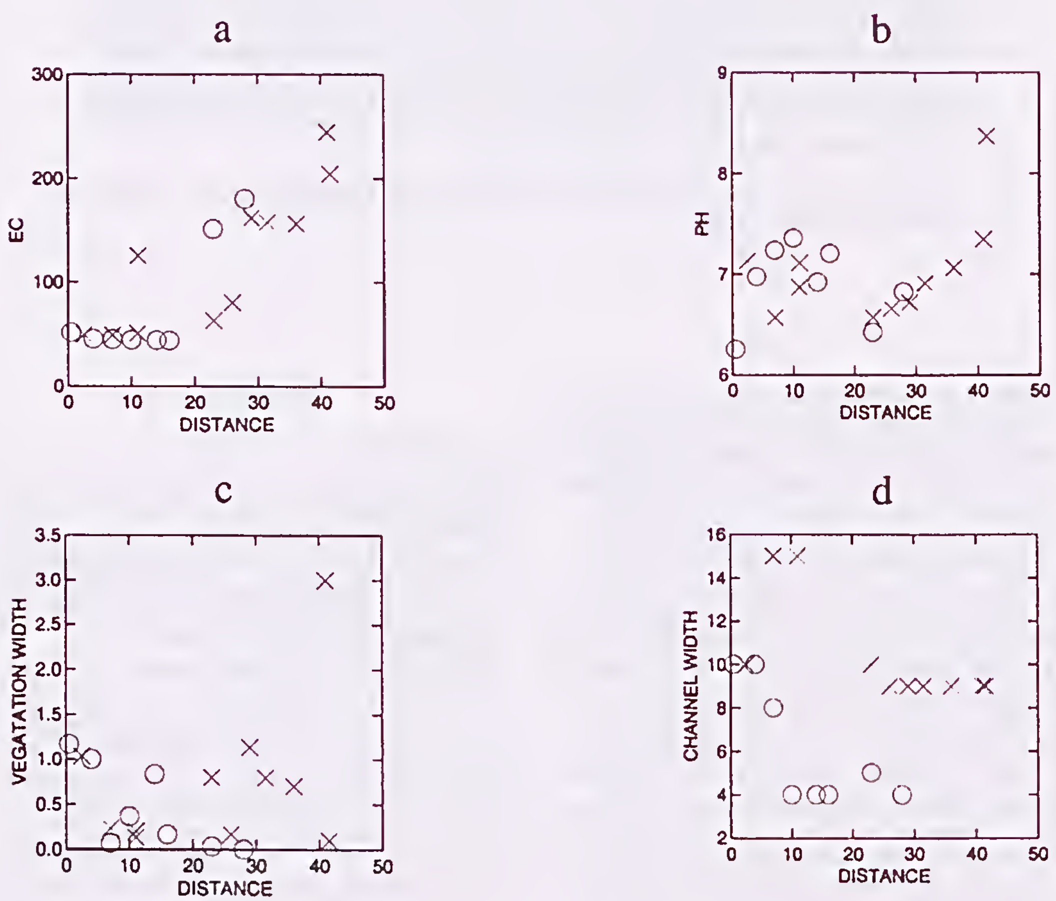

Fig 1. Relationship between distance downstream (km) from the Stuart Murray Canal and (a) EC (µS cm^{-1} @ 25°C), (b) pH, (c) vegetation width (m) and (d) channel width (m) where X = Channel 4 and O = Channel 2. Note the mean of the three replicate measurements is shown.

Irrigation channels are periodically treated with pesticides to control aquatic macrophytes. As this would affect the habitat of macroinvertebrates and possible directly affect the macroinvertebrates, the two channels were chosen at a time when neither had been treated with any pesticide for at least two years prior to sampling (P. Butcher & P. Dickenson, Goulbourn–Murray Water, Tatura, pers. comm.). The land use in the vicinity is irrigated pasture for dairy cattle and irrigated fruit trees.

Sampling method

Sampling was conducted between 5 and 7 February 1996, at 11 sites in Channel 4 over approximately 40 km and eight sites over approximately 30 km in Channel 2. The distance to each site from the Stuart Murray Canal was measured from 1:100 000 topographical maps and was used to investigate longitudinal relationships in the channels. At each site three replicate samples were randomly taken using a standard sweep with a net (mesh size 250 μm) with each sample taken from approximately 4 m length of channel. The net was swept through any macrophytes present and along the bank of the channel.

A Horiba Waterchecker (U10) was used to measure electrical conductivity (EC) (μS/cm @ 25°C), pH, dissolved oxygen (DO) (mg/L) and water temperature (°C) after calibration. The width of both the macrophyte band and the channel were recorded. Measurements of other habitat variables known to affect macroinvertebrates, such as particle size of substrate, riparian vegetation and shading, were not taken because visual observations judged these variables to be relatively uniform in both channels.

At each site a one-litre water sample was taken and then stored in a light proof Esky filled with ice. A Merck photometer (SQ 300) was used to measure the NO_2–N (mg/L), NO_3–N (mg/L), PO_4 (mg/L) and turbidity (NTU) of these samples at the end of each day's sampling.

Macroinvertebrates were identified to family or genus level. Identification was not taken to species level because of the considerable additional resources that would be required, probably for relatively little benefit (Marchant et al. 1995; Wright et al. 1995).

RESULTS

Water quality and habitat

Water quality in terms of salt, temperature and pH was good compared to what would be expected in a degraded floodplain stream in Victoria (Ladson et al. 1999). However, water clarity and nutrient concentrations did reach quite low/high levels, respectively, in a few samples (Table 1).

In both channels, EC, turbidity, NO_2–N and PO_4 increased with distance downstream (Figs 1, 2; Table 2). Note longitudinal changes in water temperature and DO are not reported due to the possible confounding effect of the time of day that a site was sampled. In addition to the water quality variables, both channels tended to decrease in width downstream because of the use of water for irrigation. Although the above water quality and habitat variables all moved in the same direction with distance downstream in both channels, several differences existed between the two channels. At a given distance turbidity, NO_2–N and PO_4 tended to be greater in Channel 2 than Channel 4, while the reverse was true with channel width (Figs 1, 2; Table 1). Additionally, EC stayed constantly low for longer and rose to a lower maximum in Channel 2 than Channel 4 because of differences in downstream saline water disposal. There were other differences between the two channels. NO_3–N concentration decreased only in Channel 4 with distance downstream (Fig. 2a). Only in Channel 2 did aquatic vegetation on the banks tend to decrease in width with distance downstream (Fig. 1c).

Due to several of the water quality and habitat variables being correlated with distance downstream, the patterns in the multivariate combination of these variables was investigated using correlation-based principle component analysis (PCA). The dominant trend in the multivariate combination was longitudinal, represented by Factor 1 (Fig. 3). There was also a difference in the multivariate combination of water quality and habitat variables between the two channels as represented by Factor 2 (Fig. 3). The differences in Factor 1, and thus the two channels, was associated with vegetation width, pH and EC and, to a lesser extent, nitrate (NO_3–N) (Fig. 4). While Factor 2, and thus the longitudinal trend, was associated with nitrite (NO_2–N), PO_4 and channel width (Fig. 4).

Macroinvertebrates

Fifty-eight macroinvertebrate taxa from 50 families and two fish species were identified from the channels. Taxa richness and total number of macroinvertebrates decreased significantly at the 0.05 level with distance downstream in both channels

	EC	pH	NO_3–N	NO_2–N	PO_4	Turbidity	Vegetation width	Channel width
Transformation	nil	nil	nil	log_{10}	log_{10}	log_{10}	nil	nil
Channel 2	**r = 0.83, P = 0.011**	r = –0.038, P = 0.929	r = –0.38, P = 0.354	**r = 0.74, P = 0.034**	**r = 0.84, P = 0.011**	**r = 0.89, P = 0.003**	**r = –0.73, P = 0.040**	**r = –0.77, P = 0.024**
Channel 4	**r = 0.85, P = 0.001**	r = 0.47, P = 0.144	**r = –0.65, P = 0.030**	**r = 0.99, P < 0.001**	**r = 0.75, P = 0.009**	**r = 0.76, P = 0.029**	r = 0.39, P = 0.235	**r = –0.73, P = 0.011**

Table 2. Correlations between distance downstream (km) from the Stuart Murray Canal and water quality and habitat variables in the two channels. Correlations significant at the 0.05 level are in **bold**.

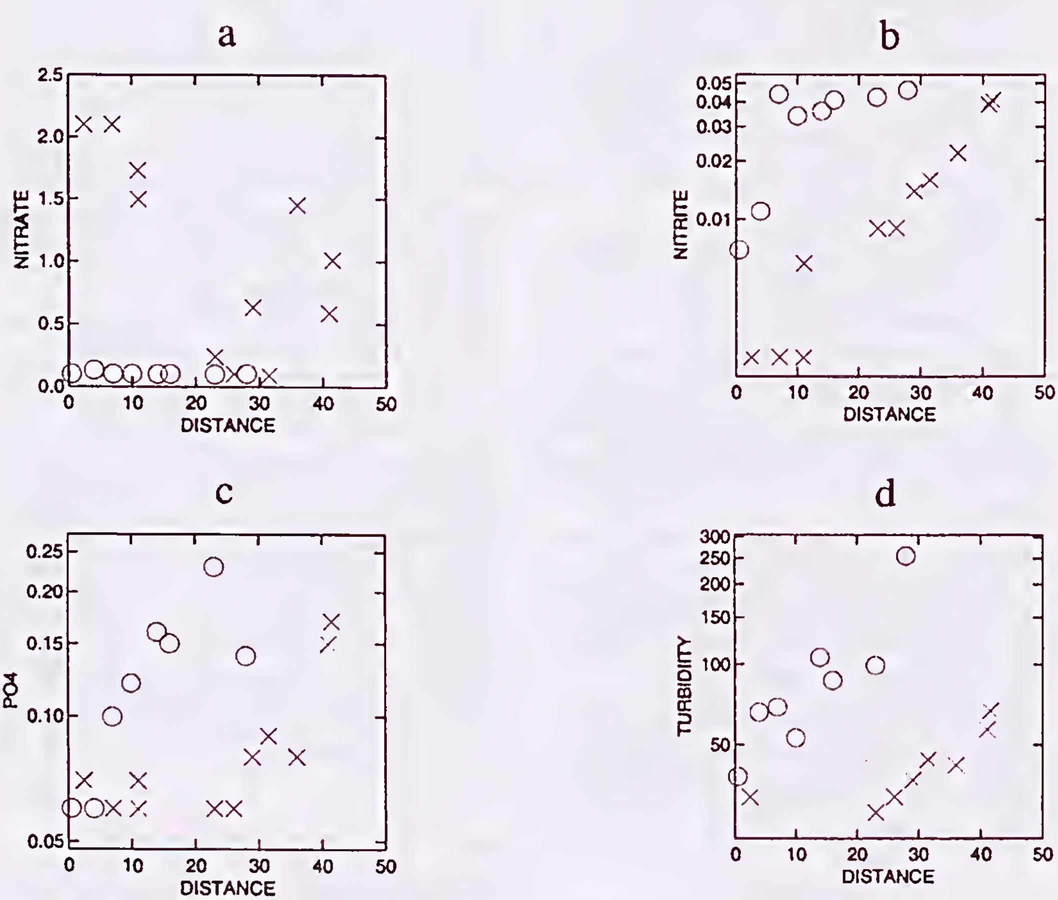

Fig 2. Relationship between distance downstream (km) from the Stuart Murray Canal and (a) NO_3–N or nitrogen as nitrate (mg/L), (b) NO_2–N or nitrogen as nitrite (mg/L), (c) PO_4 (mg/L) and (d) Turbidity (NTU), where X = Channel 4 and O = Channel 2. Note the log_{10} Y-axis for all graphs except (a).

(Figs 5, 6). Despite the differences in water quality and habitat the above relationship with taxa richness did not differ significantly between the two channels ($F = 1.074$, $df = 1, 16$, $P = 0.313$). While the relationship with total number of individuals only differed by a marginally statistically significant amount ($F = 3.101$, $df = 1, 16$, $P = 0.094$), clearly the longitudinal differences within a channel were

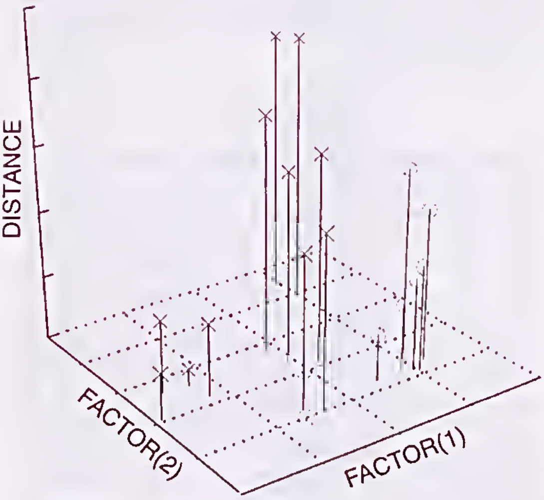

Fig 3. PCA ordination plot, where X = Channel 4 and O = Channel 2 and the higher the spike the further downstream the sample is from the Stuart Murray Canal (km). Note Factor 1 explains 46% of variance in the water quality and habitat parameters and Factor 2 explains 22%.

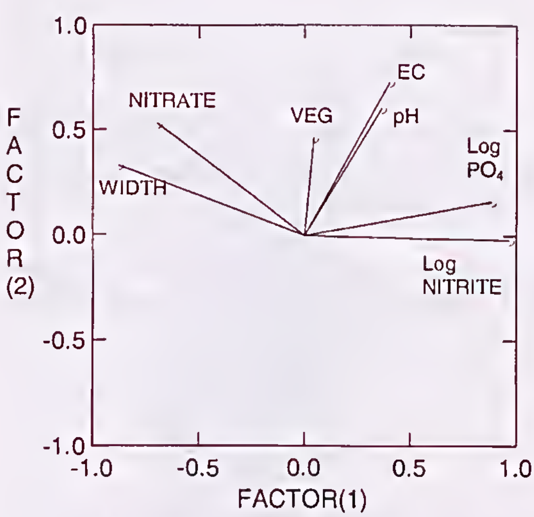

Fig 4. Factor loading plot. Note turbidity is not included as it was mistakenly not measured at 3 sites, VEG = vegetation width, WIDTH = channel width and other variables as labelled.

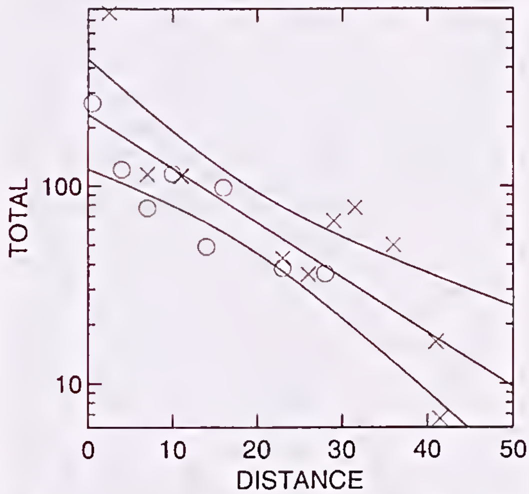

Fig 5. Relationship between distance downstream (km) from the Stuart Murray Canal and total number of individuals per sample (TOTAL), where X = Channel 4 and O = Channel 2. Note the log scale and the mean of the three replicate samples is shown. Regression line and 95% confidence limits are calculated from data from both channels, $r = -0.83$, $P < 0.001$.

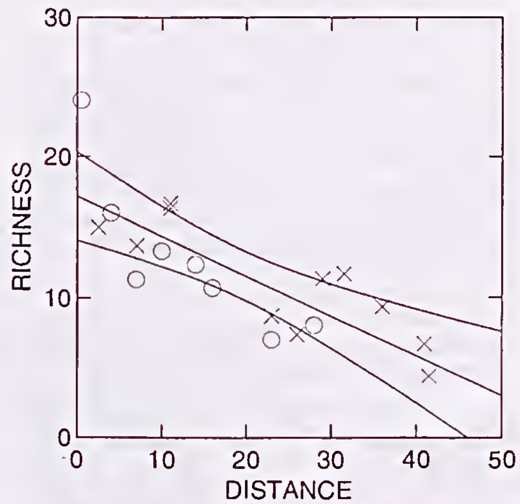

Fig 6. Relationship between distance downstream (km) from the Stuart Murray Canal and taxa richness (RICHNESS), where X = Channel 4 and O = Channel 2. Note the mean of the three replicate samples is shown. Regression line and 95% confidence limits are calculated from data from both channels, $r = -0.80$, $P < 0.001$.

much greater than any differences between the channels (Figs 5, 6). Furthermore, the relationship between taxa richness and distance downstream was stronger than the relationships between taxa richness and the PCA factors (Table 3) and the measured water quality and habitat variables. Similarly, the same situation applied with total number of individuals. Consequently the correlations between taxa richness and the total number of macroinvertebrates and water quality parameters were calculated after taking into account the relationship with distance downstream. These correlations are known as partial correlations (Table 4). Only one of these partial correlations was significant at the 0.05 level. however, due to 16 multiple comparisons, this result may have been due to chance. Thus after taking into account the effect of longitudinal changes along the channels, there was little or no measurable effect of the water quality parameters measured. This implies that either some combination of the measured water quality and habitat parameters or some factor(s) correlated with them were the cause of the longitudinal changes in macroinvertebrate fauna.

Of the 58 macroinvertebrate taxa, 29 were considered abundant enough to conduct univariate analyses (Table 5). The abundance of 18 of the common taxa decreased with distance downstream (km) at the 0.05 level and an additional taxon decreased at the 0.1 level (Table 5). In contrast one taxon increased in abundance at the 0.1 level.

Macroinvertebrate data was $\log_{10}(x+1)$ transformed and the Bray–Curtis similarity coefficient was calculated between sites. The resulting triangle matrix was ordinated using the specific method of multi-dimensional scaling (MDS), with the aid of the software PRIMER. The ordination showed longitudinal trends within the channels and some difference in the longitudinal trend between the two channels (Fig. 7).

DISCUSSION

Unlike natural streams, irrigation channels receive little agricultural runoff due to their elevation above the surrounding land and the presence of the levee banks along the channel. Consequently, the water quality changes are unlikely to be a direct consequence of agricultural activities on the surrounding land. The increase in electrical conductivity is almost certainly due to the disposal of saline groundwater as the increases coincide with points of saline water disposal. As NO_3 in groundwater can be quite high (Harrison 1994) and the majority of the nitrogen in groundwater around Shepparton is NO_3 (Bauld 1991), the increase in NO_3–N in Channel 4 is likely to be due to the groundwater disposal. The increase in NO_2–N cannot be solely explained by NO_3, from the groundwater, oxidising to NO_2 because NO_2–N increased in Channel 2 upstream of any groundwater disposal.

	Factor 1	Factor 2	Factor 3
Richness	**r = –0.59, P = 0.008**	r = –0.33, P = 0.162	r = –0.15, P = 0.541
Log_{10} total	**r = –0.59, P = 0.008**	<u>r = –0.40, P = 0.094</u>	r = –0.05, P = 0.836

Table 3. Correlations between macroinvertebrate summary statistics and PCA factors. Correlations significant at the 0.05 level are in **bold** and those significant at the 0.1 level are <u>underlined</u>.

Parameter	Partial correlation with taxa richness	Partial correlation with total no. of macroinvertebrates
EC	r = 0.33, P = 0.176	r = 0.22, P = 0.376
pH	r = –0.20, P = 0.426	r = 0.17, P = 0.507
Nitrate (NO_3–N)	r = 0.14, P = 0.584	<u>r = 0.46, P = 0.056</u>
Nitrite (NO_2–N)	**r = –0.48, P = 0.044**	r = –0.30, P = 0.263
PO_4	<u>r = –0.44, P = 0.062</u>	r = –0.13, P = 0.609
Turbidity	r = –0.24, P = 0.334	r = –0.23, P = 0.407
Vegetation width	r = 0.39, P = 0.101	r = 0.30, P = 0.219
Channel width	r = 0.39, P = 0.108	r = 0.07, P = 0.789

Table 4. Correlations between macroinvertebrate summary statistics and water quality/habitat parameters after taking into account effect of distance downstream from the Stuart Murray Canal. Correlations significant at the 0.05 level are in **bold** and those significant at the 0.1 level are <u>underlined</u>.

Order	Family	Genus species	Decrease	Increase
Amphipoda	Ceinidae		**	
	Eusiridae		**	
	immature		**	
Decapoda	Atyidae	*Paratya australiensis*	**	
	other Atyidae			
	Parastacidae	*Cherax destructor*		
Cladocera		*Daphnia*	**	
Ostracoda			**	
Anostraca	Branchinella			
Gastropoda	Ancylidae	*Ferrissia*	**	
Diptera	Chironomidae		**	
	Culicidae		*	
Coleoptera	Dytiscidae		**	
	Staphilinidae		**	
Copepoda	Cyclopoda		**	
	Calanoida			
Ephemeroptera	Caenidae		**	
	Baetidae			
	Leptophlebiidae			
	immature			*
Hemiptera	Corixidae		**	
	Notonectidae			
	Mesoveliidae			
Trichoptera	Hydroptilidae		**	
	Leptoceridae			
Odonata	Lestidae		**	
	immature		**	
Araneae			**	
Hydracarina			**	

Table 5. List of the 29 most abundant taxa recorded. Taxa with a significant decrease or increase in abundance with distance downstream of the Stuart Murray Canal (km) are shown (**P < 0.05; *P < 0.10).

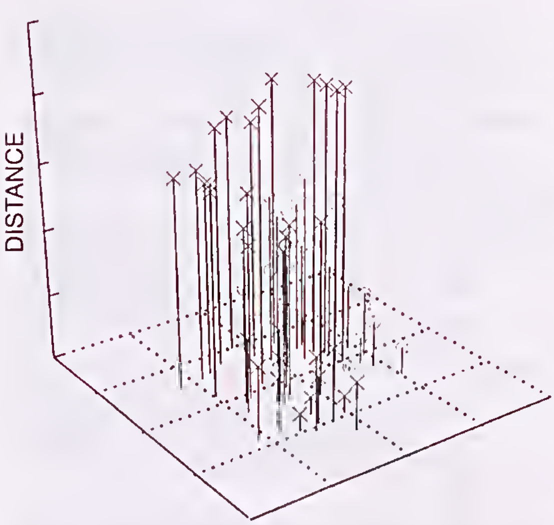

Fig 7. Ordination plot, where X = Channel 4 and O = Channel 2 and the higher the spikes the further downstream the sample is from the Stuart Murray Canal (km). Note, ordinated in three dimensions and stress = 0.17.

The dominant pattern in macroinvertebrate fauna is a decline in the abundance and richness of the community with distance along the channels, which parallels the changes in water quality. Similarly, community structure, as evidenced by ordination scores, changed consistently with distance downstream in both channels. After taking into account this longitudinal change in the macroinvertebrate fauna, the measured water quality parameters were relatively poorly correlated with the richness and the abundance of the macroinvertebrate community. Interestingly, the longitudinal change in taxa richness and total number of individuals were very similar in both channels, despite some differences in the longitudinal trends in water quality and habitat variables changing between channels. Furthermore, several of the water quality variables that changed in a similar direction in both channels did so starting from different baselines, and finishing at different levels. These observations suggest that measured water quality and habitat variables in each channel cannot totally explain the similarity in the longitudinal changes in macroinvertebrate fauna.

Longitudinal changes in macroinvertebrate fauna in natural rivers are well known (Marchant et al. 1999) and several theories have been proposed for these changes (Vannote et al. 1980; Statzner & Higler 1986). However, the magnitude of the changes observed in the irrigation channels was considerably greater than commonly observed in natural rivers. In the current study, the total number of taxa per sample decreased by approximately 0.3 of a taxon per km of irrigation channel. This compares to Marchant et al. (1999) who examined macroinvertebrate fauna at 199 sites in natural rivers throughout Victoria and found longitudinal changes in community structure, but did not find any relationship between the distance of a site from the source of the river and species richness.

The occurrence of longitudinal patterns in both irrigation channels and natural rivers is made more interesting as the volume of water flowing, width and depth in irrigation channels decreases with distance downstream due to the use of water for irrigation. In natural rivers, these factors usually increase due to greater upstream catchment area. Additionally, longitudinal changes in substrate composition and riparian vegetation that commonly exist in natural rivers do not occur in irrigation channels. Studies comparing longitudinal patterns in biota, water quality and habitat in both irrigation channels and natural rivers may provide a useful environment to investigate the causes of longitudinal patterns in stream biota.

Macroinvertebrate surveys of waterways in rural landscapes are comparatively rare. However, the number of macroinvertebrate taxa collected in the two channels (50 families) is relatively large, especially when compared to natural streams that have undergone some disturbance in northern Victoria. While differences in sampling regimes make comparisons somewhat difficult, Tiller (1991) collected only 27 families from 8 sites in Fifteen Mile Creek, a tributary of the Ovens River polluted with waste water discharge. In Bendigo Creek, up and downstream of Bendigo, Metzeling & Pettigrove (1988) collected only 39 families from 6 sites. While irrigation channels do not have the complex habitat found in rivers, such as large woody debris, floodplains, undercut banks, meanders and complex currents, significant amounts of habitat are found in the fringing vegetation along the banks. Although irrigation channels are not presently designed for biodiversity benefits, there appears to be a relatively rich fauna associated with the channels, especially in their upstream sections.

As diversion of water from rivers into the channels places stress on rivers downstream of the diversion, the channels as presently designed provide habitat for some stream species. However, it was evident that the biodiversity value of the two channels under investigation diminished with distance downstream. It may be possible to alter the design and manage channels to increase the biodiversity value they provide. Two design and management measures that could be introduced to existing irrigation channels that are likely improve their habitat value include: riparian vegetation for shading and debris and the minimal use of pesticides in channels. However, there is a large amount of research and development needed before specific recommendation can be made.

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